Competition and industrial coordination

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1. INTRODUCTION

This chapter aims at studying the adjustment process implemented by competing firms. The process of competition between firms may lead to different positions. Competition may arrive at perfect coordination and the adjustment process exhibits a convergence to an equilibrium. Competition may also imply a more problematic position of imperfect coordination and the emergence of durable and cumulative disequilibria. In both situations, specific institutional arrangements such as mergers and acquisitions, cooperation and alliances have to be elaborated by firms to prevent the occurrence of these disequilibria and, to some extent, to organise the process of competition. In fact, the role of business institutions is different with respect to each type of coordination. Being considered as a simple response to market failures when coordination is perfect, they must be endowed with a more endogenous status when coordination is imperfect.

To analyse these issues, we will assume that, within the competitive process, interacting firms are facing two problems at the same time. Firms have to acquire a productive knowledge (how can the productive capacity be developed?) and a market knowledge (how do other firms behave?). We will argue on the one hand that, if productive knowledge is perfect, the concern is only in the treatment of market coordination. On the other hand, if both market and productive knowledge are imperfect, the concern is in what we may label the 'coordination of industry'.

In the analysis of market coordination, general equilibrium economics had for a long time led economists to be used to represent a system of decentralized market interactions by the abstract device of centralized coordination. In fact, general competitive equilibrium theory is essentially 'top-down' for, in the absence of externalities, it reduces to the optimal solution of a social planner's problem. Using a computer analogy,

Leijonhufvud has advocated a 'bottom-up' view of the system where 'the economy is best conceived of as a network of interacting processors' (Leijonhufvud, 1993). While centralized top-down coordination can work with static and perfect information hypotheses, decentralized bottom-up coordination is naturally characterized as a dynamic step-by-step problem solving process. In this case institutions and behavioural conventions emerge to cope with partial ignorance and strong uncertainties affecting the individual agent. We shall see in the next section that there have been two ways of treating the link between market coordination and institutions from a bottom-up point of view. Hayek argued that coordination of dispersed knowledge is mainly dedicated to the acquisition of market knowledge, while Marshall developed a notion of organization which opens the way to analysing industry.

In the analysis of industrial coordination, the releasing of the perfect productive knowledge assumption, along with the assumption of perfect market information, shows a limited ability of agents to process information and to coordinate their activities in a complex and unstable environment. Thus the main requisite of bottom-up coordination is 'computational feasibility' (ibid.). That is, decision rules and learning procedures, including expectations formation, should be capable of algorithmic representations. In this case, we shall use in the third section the work of Richardson to propose an algorithm where decision making in production processes serves as a computational device for the market process. Referring to this framework, we will show that competition is a dynamic process based on recurrent coordination failures. Within this process firms have to implement institutional arrangements (integration, cooperation or market relation) to avoid dramatic disequilibria.

2. MARKET COORDINATION AND INSTITUTIONS

The assumption of imperfect market information in the theory of prices makes it necessary to consider the market as an institution. This comes from the idea that institutions may in some way compensate for the unavailability or dispersion of market knowledge. We will show that, in Hayek's analysis of competition, the prevalence of a market order suggests the existence of perfect coordination where institutions are essentially exogenous to the adjustment process. In Marshall's work, on the contrary, there is an essential recognition that the adjustment process can fail and may lead to imperfect coordination. The focus on internal business organization and external trade connections, together with the linking of knowledge and organization, tends to make institutions endogenous in the description of competition.

2.1. Division of Knowledge and the Adjustment Process

The coordination problem has been stated in terms of knowledge and information by Hayek in 'Economics and Knowledge' (Hayek, 1937). In this article, the author dismisses the static allocative efficiency criterion of the 'Pure Logic of Choice' to the benefit of a coordination process perspective. According to Kirzner, this is a step logically prior to the operation consisting in allocating given resources to pre-established ends (Kirzner, 1982, 1984). To study the coordination process is to analyse the tendency towards equilibrium, which means that the knowledge of the different members of society comes more and more into agreement and that the expectations of individuals, particularly of the entrepreneurs, become more and more correct. This implies taking into account the problem of 'the *division of knowledge* which is quite analogous to, and at least as important as, the problem of the division of labor' (Hayek, 1937, original emphasis). The former has been neglected, although it seems 'to be the really central problem of economics as a social science'. That is (ibid., pp.50–51):

> how the spontaneous interaction of a number of people, each possessing only bits of knowledge, brings about a state of affairs in which prices correspond to costs, etc., and which could be brought about by deliberate direction only by somebody who possessed the combined knowledge of all those individuals.

The only relevant knowledge different people must possess in order that equilibrium may prevail is the one they acquire in carrying out their original plans. They do not dispose of all the information, especially the information which, 'if acquired by accident', would lead them to change their plans. Therefore this equilibrium is not an optimum position. Further conditions should be met in order that 'the results of the combination of individuals bits of knowledge should be comparable to the results of direction by an omniscient dictator' (ibid., p.53).

These references to deliberate direction, omniscient planner or 'directing mind' (ibid., p.54), even if alluded to in the negative, reveal the difficulties met in attempting to treat theoretically the division of knowledge (cf. Böhm, 1995, pp.162–3). Even if market knowledge can be considered as a social device which cannot be acquired individually, 'Hayek conveys the impression . . . that the outcomes of competitive market transactions are independent of the processes generating them' (ibid., p.162). This inability to solve analytically the problem of convergence to equilibrium in 'Economics and Knowledge' led to 'Hayek's transformation', identified by Caldwell (1995), involving a turning away from a theory of learning and expectation formation to the more pragmatic task of investigating the use of dispersed or fragmented knowledge according to different institutional arrangements. The

historical emergence and extension of the competitive market became the main topics of the author's work (Ege, 1992). Spread out all over this work, they constitute the subject matter of a number of articles proposing a critical reading of price and exchange theory.

'The Use of Knowledge in Society' (Hayek, 1945) deals more precisely with the problem confronted by society to make a rational economic order emerge in a situation where the separate individuals only possess 'dispersed bits of incomplete and frequently contradictory knowledge' (ibid., p.519). The economic problem of society is not merely one of allocating given resources, but mainly one of 'rapid adaptation to changes in the particular circumstances of time and place' (ibid., p.524). The real function of competitive market is to coordinate the separate actions of different people with the price system which is 'a mechanism for communicating information' (ibid., p.526). The level of knowledge necessary to individual participants in this system is very low, being compensated by 'constant use of formulas, symbols and rules whose meaning we do not understand' and by the development of 'practices and institutions'. The price system is one of those formations 'which man has learned to use . . . after he had stumbled upon it without understanding it' (ibid., p.528). Starting from this notion of dispersed knowledge, the basic idea is to define the market as the locus of a 'process of competition' as opposed to competition as a 'state of affairs' used in price theory where the essential characteristics of a dynamic process has been assumed away (Hayek, 1946). Competition itself is defined as a 'discovery procedure' (Hayek, 1978) the operation of which leads to an 'order'. This order, 'being approached to various degrees' and 'preserved throughout a process of change', is different from the notion of an economic equilibrium which 'never really exists' (ibid., p.184).

In spite of the open-endedness and creative aspects of the market process as described by Hayek, the critical function of his analysis is reduced by the teleological aspect of his notion of an economic order constitutive of these processes. The analogy between market adjustments and the results obtained by an 'omniscient dictator' already noticed in our comment on Hayek (1937) must be compared to the statement that, although the specific outcomes of a discovery procedure are in their nature unpredictable, 'the market order produces in some sense a maximum or an optimum' (Hayek, 1978, p.183).[1] What one may conclude from these remarks is that the procedure of decentralized coordination as expressed by Hayek always tends towards an order which is defined outside the economic sphere. In the words of Foss (1995, p.29), 'Hayek (1937) was content with stating the co-ordination problem, and then later on seeking a solution to it outside economics, namely in classical liberalism's traditional emphasis on evolved institutions and how such institutions stimulated spontaneous orders'.

Thus the role of institutions is reduced to the confirmation of 'the empirical observation that *prices do tend to correspond to costs*' (Hayek, 1937, p.51, emphasis added). It only shows that the coordination procedure cannot fail, so that there is no need for the agents to compute this 'spontaneous order'. In Hayek's analysis, the adjustment process is definitely a spontaneous process leaving no role to computation. Thus, to construct an analysis of the adjustment process, it becomes necessary to consider endogenous institutions that make this computation possible.

Investigating the problems of information related to the perfect competition model, Leijonhufvud (1968, p.70) quotes Hayek's (1945) remark about how little the individual participants in the price system need to know in order to take the right action, and argues that what the individual transactor needs to know is precisely the equilibrium prices. When one tries to interpret the abstract competitive model as an actual process, there emerge two features (Leijonhufvud, 1968, p.70):[2] '(a) the information required by individual transactors is ''produced'' apart from the actual process of exchange (and production) and (b) it is ''distributed'' at no cost to transactors'.

Thus there appears the necessity of investigating how some kind of institutional arrangement emerges to do the coordinating job. In fact, computable economics has to be set into some institutional context, so as to ensure 'computational feasibility'.

Even a centralized top-down general equilibrium system needs some organization, as soon as it is considered as a concrete issue. Taking as a point of departure a model with a central coordinator, as in the case of established general competitive analysis, Clower and Leijonhufvud (1975) modify it so that it can be used to deal with real and not only virtual disequilibria. This implies getting rid of the two hypotheses pointed out above, so that: (a) trades can take place at prices that do not ensure the collective consistency of individual plans, and (b) transactions are costly. From this follows the model of the 'central supermarket' where individual agents can in pairwise fashion trade at will any one good for any other, under the control of a 'central trade coordinator'. This coordinator is holding such quantities of tradable commodities as to meet the requirement that individuals may be able to trade at dates and in amounts they choose, and determines exchange rates so as to meet operating expenses and adjust aggregate inventories through time. Under some appropriate requirements ensuring that this economy behaves not too irrationally (or reasonably enough), the existence and stability conditions of equilibria can be derived. However, the existence conditions appear to be rather artificial. The organized barter economy portrayed by the supermarket model necessitates that the coordinator deal in every kind of commodities, including employment contracts, future contracts and so on, in

the same way as spot trading of physical objects. The protection against opportunism, fraud or overcommitments would need such costly monitoring and enforcement devices that this kind of uneasy and long-term contracts should be 'severely limited' (ibid., p.185). The same applies to stability which is less conditioned by mechanical reactions of the model than by the necessity of invoking some 'reasoned and intelligent decisions of the trade coordinator' (ibid., p.186).

Such clauses are designed to set limited magnitude and bounded duration to departures from equilibrium in a barter economy, showing through the institutional requirements for informational structures and incentives schemes used in modern microeconomics theory. Nevertheless, all these pseudo-institutional forms cannot protect the system from being threatened by the occurrence of coordination failures, as soon as a substantial proportion of traded commodities are highly durable goods or, worse, if monetary or credit complications are introduced into the model. These coordination failures then become violent and cumulative.

2.2. Knowledge and Organization: Internalizing Institutions

When institutions are maintained outside the analysis of equilibrating processes, they are only used as an explanation of the existence of an economic order towards which the system will tend spontaneously. Conversely, when institutions are part of the process, they can be considered as playing a more effective role in compensating coordination failures. Internalizing institutions thus gives to the analysis a more realistic content, in the sense that one may consider now that the coordination process can fail. The problem is essentially to answer the question why aggregate outcomes of rational agents' interaction could be less rational than the Austrian 'market order' defined as the unintended result of purposeful individual actions.

The emergence of effective intermediate institutions (middlemen, specialized merchant traders or organized markets) becomes an analytical necessity in dealing with such a coordination problem where there is no medium course between ultrarational stability and chaotic unstability. As far as a real organization of trade is concerned, the work of Marshall naturally comes into play. In fact, '[M]arshall's economics . . . *is not based on choice theory* [but rather on] simple feedback-based *decision rules* in less than completely known environments' (Leijonhufvud, 1993, p.9, original emphasis).

Knowing the marginal utility of money and having a subjective marginal utility function for each separate good, the boundedly rational consumer follows a sequential process of consecutive buying decisions ending up with the exhaustion of his or her budget constraint. This process is open to error in

that prices are discovered one after the other, so that it can be corrected before spending next month's wages.

The notion of Marshallian competition as a real discovery procedure is more specifically studied by Loasby (1989, chap.4 ; 1990). It is argued that Marshall's theory of economic progress, as well as his theory of coordination, were based on the relationship between knowledge and organization, the 'twin themes' of Book IV of Marshall's *Principles* being 'the effects of the growth of knowledge on organisation and costs of production, and the effects of the organisation of production on the growth of knowledge' (ibid., p.54). In Marshall's own words (Marshall, 1920, p.115):

> Capital consists in a great part of knowledge and organisation . . . Knowledge is our most powerful engine of production . . . Organisation aids knowledge; it has many forms, *e.g.* that of a single business, that of various businesses in the same trade, that of various trades relatively to one another, and that of the State providing security for all and help for many.

Indeed, this description draws a more complete picture of the organization of industry than the usual industrial organization literature. Beginning his chapter on 'Industrial Organisation' (Marshall, 1920, book IV, chap. VIII), the author combines the Smithian division of labour with Darwinian theory, pointing out 'the many profound analogies which have been discovered between social and especially industrial organisation on the one side and the physical organisation of the higher animals on the other' (ibid., p.200). In fact, there is:

> a fundamental unity of action between the laws of nature in the physical and in the moral world. This central unity is set forth in the general rule, to which there are not very many exceptions, that the development of the organism, whether social or physical, involves an increasing subdivision of functions between its separate parts on the one hand, and on the other a more intimate connection between them. (Ibid., p.200–201)

The ways in which the various forms of organization aid knowledge and knowledge improves organization, thus making coordination possible, are not really presented in a well structured fashion by Marshall. Nonetheless, Loasby has spent a good deal of energy and ingenuity in regrouping the elements scattered through the *Principles* and *Industry and Trade*, and constructing a convincing picture of the coordination problem treated by Marshall as a consequence of both the division of labour and the division of knowledge (see Loasby, 1989, 1990, 1994). The most significant result of this reconstruction is certainly the one which relates internal business organization and external trade connections to the processes leading to internal and external economies, these processes being much more a matter

of improvements in knowledge and organization than a matter of standard definition in terms of scale economies. See, for instance, Marshall's wording of the 'law of increasing returns': 'An increase of labour and capital leads generally to improved organisation, which increases the efficiency of the work of labour and capital' (Marshall, 1920, p.265). As pointed out by Loasby (1989, p.57), Marshall draws attention to 'the length of time that is necessarily occupied by each individual business in extending its internal, and still more its external organisation' (Marshall, 1920, p.414). The term 'external organisation' suggests 'the network of social, technical and commercial arrangements which link a business with its customers, suppliers (who are usually of many kinds), and also its rivals, whose own experiments provide it with both incentive and information' (Loasby, 1989, p.57). Moreover, for all information dispensed by these trade connections, prices cannot be 'sufficient statistics' (Loasby, 1994, p.259). Therefore, contrary to Hayek's treatment of the same subject, Marshall's analysis of price is based on an institutional foundation which internally provides the means of coordination.

The consequences for an adjustment theory are the following. The coordination of the economic system should be described through trade connections linking firms one another in a process implying both market and productive information, as well as market and productive organizations. This leads naturally to Richardson who, as an 'Austrian Marshallian' (Foss, 1995), developed the Hayekian theme of the division of knowledge and the Marshallian theme of the link between knowledge and organization. These themes turn directly on issues of industrial coordination and the role of business institutions in this adjustment process. Indeed, Richardson 'sought a solution to the co-ordination problem that was internal to economic theory' (ibid., p.29).

3. INDUSTRIAL COORDINATION AND BUSINESS INSTITUTIONS

A situation in which both imperfect market and productive knowledge are simultaneously experienced leads to the threat of coordination failures that could result in the occurrence of durable and cumulative disequilibria between supply and demand. However, integrating the productive dimension in the way Richardson does will allow us to work out a 'computational algorithm' for both decision rules and learning procedures, whereas economists generally give up searching for an explanation of coordination in such a complex situation. More than simply coping with an intricate situation, the algorithm we propose highlights the function that business

institutions have to perform with regard to the coordination problem.[3] Within the process of competition the role of these institutions is to ensure industrial coordination and not only informational coordination.

3.1. Market and Productive Knowledge

3.1.1. Defining an algorithm of decision in a complex environment

In a 1959 paper, Richardson introduces two types of information, namely 'primary information' and 'secondary information'. Primary information when imperfect implies that the technique of production may evolve through time in a way which is not always known or even predictable by the firm itself. Capabilities have to be developed step by step by the firm, if need be through the joint effort of other firms. Secondary information when imperfect implies that the market behaviours of other firms are not known by the firm. Within this framework, an acquisition of productive knowledge problem is added to the existing problem of access to market knowledge we referred to in the preceding section.[4] Market knowledge relates to the strategic activities which are engaged in by the competitors of a given firm, but also by its customers, suppliers or partners. Productive knowledge characterizes the specific investments which are implemented by this firm, either by itself or in cooperation with other firms. These two problems are also defined in terms of 'delays' or 'time periods' (cf. Richardson, 1960) because the acquisition of these two types of knowledge is delayed through time: market knowledge and productive knowledge will be acquired by the firm only after a lapse of time, the length of which is unknown by the firm.

The profitability of the investment of a given firm 'F' is then submitted to a couple of different delays: (a) the 'information transmission period', meaning that information concerning the strategic decisions of other firms (different from F) will appear only after a certain lapse of time, and (b) the 'investment gestation period', which means that receipts of the investment of the firm F will be available at the end of an irreducible and uncertain period.

Furthermore, in order to control the profitability of its investment, firm F has to face two kinds of investments constraints: (a) 'competitive investments' which, if they are engaged in by other firms and, especially by rivals, will decrease the profitability of the investment of firm F, and (b) 'complementary investments' which, if they are effectively implemented by firm F or by a group of cooperating firms, will increase the profitability of the investment of firm F.

If the respective lengths of the two defined periods were known, the problem of the firm would be easily solvable, using an optimization programme. In our case, however, these lengths are simply unknown by firm F, so that an equilibrium cannot be found. Economists are often discouraged

from asking such a complex question, mainly because it cannot be solved in equilibrium and rational behaviour terms. This question can be answered if we move to a computable economics analysis. As Leijonhufvud (1993, p.5) puts it: 'The rule for Computable Economics modelling will be that you may assume as much ''rationality'' on the part of decision-makers as you want as long as you can also specify a corresponding implementable algorithm by which they could make decisions'.

Our basic point is to describe a situation in which firms are only endowed with local, private and tacit knowledge. These firms implement competencies in developing specific production plans, and they take decisions from a limited information set. Because the industrial system is based on interactions between firms of this kind, it may experience coordination failures implying that erroneous choices are necessarily made, and disequilibria between supply and demand are observed (Richardson, 1960, chaps III and IV). The crucial issue is then to avoid the persistence of such disequilibria through time and to limit their cumulative effects. To achieve this result, firms have to maintain the industrial system between some threshold limits, that is within what could be called a viability corridor.

Taking into account the assumptions about information transmission and investment gestation delays made above, the algorithm takes the following form for firm F:

Develop some 'elements of control' in order to:

- *maintain competitive investments under a maximum threshold level.* The volume of competitive investments can be determined by available demand. In order to ensure profitability, firm F has to restrict the actions of its rivals. In this case, the elements of control come in the form of constraints and inertia so as to maintain market shares of firm F;
- *maintain complementary investments over a minimum threshold level.* In order to ensure profitability, firm F has to implement mutual actions with other firms. In this case, the elements of control are implemented so as to maintain the continuity of the production process. Firm F has to ensure the sequential development of complementary investments which are engaged by firm F itself or in collaboration with other firms.

The viability of the industrial system is ensured only if the two conditions are proved simultaneously. As time passes, firm F must create a coordination of both competitive and complementary investments. This point highlights the fact that, in such an algorithm, market coordination cannot be conceived apart from productive coordination. Business institutions are implemented

because they provide a basis for 'reliable interactions' (Leijonhufvud, 1993, p.4) or 'reliable beliefs' (Richardson, 1960). In fact, these agreements help to decode this complex environment where firm F evolves by ensuring occurrence or non-occurrence of some event or the action or inaction of another firm, this latter firm being supplier, customer, partner or competitor of firm F.

3.1.2. Controlling industrial coordination through business institutions

Different elements of control may be implementable by firm F through different types of business institutions. There may be informal agreements or more formal agreements concerning price, quality, reputation, distribution and innovation strategies. The literature has focused intensively on the latter case because of the strong uncertainty involved in an innovative setting which requires a wide range of potential elements of control and business institutions to be developed. For instance, some firms may implement a strategy of 'premature announcement' for their new products (cf. IBM's case, Fisher, 1989). This strategy is intended to give time to customers (especially downstream firms) to adapt their productive or distributive structure to the upstream requirements. Other firms engage with their subsidiaries in some licensing strategies the purpose of which is to realize direct technological information transfers which in turn ensure a greater number of users. In the medium or long term, these practices may be turned into pure integration strategies. A group of firms may also organize themselves within 'technological consortia' (cf. Baumol, 1993) in order to acquire both market and productive knowledge. These different contributions are related to the debate over the institutional forms most conducive to innovation and more generally to economic growth (Langlois and Robertson, 1995a). Different points of views are expressed here. On the one hand, the evidence collected by Chandler (1977, 1990) on the emergence of giant firms at the beginning of the twentieth century, together with the economic analysis of this phenomenon by Lazonick (1991), tends to show that largely integrated firms are in the best position to develop and exploit major innovations. On the other hand, Piore and Sabel (1984) claim that small specialized firms are more flexible and better adapted to generating and adopting innovations.

This debate carries critical and unresolved issues that have led in recent years to an in-depth investigation of the link between the nature of innovation and the relevant business institutions (Teece, 1986, 1996; Langlois and Robertson, 1995b). The key dimensions are the characteristics of innovation and the availability of capabilities. In the words of Teece (1986), innovation can be either 'autonomous' or 'systemic'. When innovation is systemic this means that a simultaneous change in several stages of production has to be implemented. In this case the existing assets are obsolete and the production

of the required assets implies the development of new capabilities. When innovation is autonomous the connections between the different stages of production are well defined because of the relative standardization of the different components. The change involved by autonomous innovation is then more localized within the process of production. Moreover, concerning the availability of capabilities, three cases can be observed. Capabilities may exist in-house, they may be available outside the firm or they must be created *ex nihilo*.

With these definitions in mind, the following results are obtained. Langlois and Robertson (1995b) argue that when a major entrepreneurial opportunity requires a systemic change that an existing decentralized network is ill-equipped to handle, especially in terms of capabilities, the required business institution may be large-scale vertical integration. Conversely, when markets offer a high level of capabilities relevant to an entrepreneurial opportunity, and especially when that opportunity permits innovation to proceed in an autonomous rather than in a systemic fashion, the result may be economic growth within a vertically and horizontally specialized structure.[5] More recently, Teece (1996) has also investigated the link between innovation and business institutions by crossing the type of innovation (autonomous or systemic) with the availability of capabilities (in-house, outside, *ex nihilo* created). He exhibits different types of institutions that are prevalent in different situations. The 'Silicon Valley type' prevails when there is autonomous innovation and in-house capabilities, but also when there is systemic innovation and creation of capabilities. The 'virtual type', in which outsourcing prevails, corresponds to a situation of autonomous innovation and outside capabilities. The 'alliance (equity) type' appears when systemic innovation and outside capabilities are present. The 'multi-product integrated type' prevails in a situation of systemic innovation and in-house capabilities. Finally, in the case of autonomous innovation and creation of capabilities, both the 'Silicon Valley type' and the 'alliance (equity) type' are possible.

These two last contributions have similar purposes. Firstly, they develop a new explanation of business institutions, different from traditional ones where opportunism, hidden information and hidden action practices prevail. Secondly, they consider that the emerging type of business institutions is intrinsically linked with the problem of coordination firms have to solve.

In our framework the algorithm intuitively shows that business institutions, because of the elements of control they provide, can be implemented to avoid coordination failures. The algorithm also suggests that the nature of business institutions depends on the extent of the coordination failures, in the sense that the thresholds may be variable and that the elements of control have to be sufficient to maintain the system within these

thresholds. We will develop the argumentation by showing that the nature of agreements (informal market relation, formal cooperation, integration and so on) vary with the extent of the coordination problem of both competitive and complementary investments, this extent being expressed in terms of the delays defined above. In fact, what we are trying to do is to reintroduce the strategic dimension that, together with the capabilities dimension, governs the coordination problem.

3.2. The Coordination Problem and the Role of Institutions

The core of our argumentation is that the occurrence of a coordination failure is strictly conditioned by the very presence of the two delays related to information transmission and investment gestation. The role of business institutions within industrial coordination will be demonstrated only when these two delays are simultaneously taken into account. However, we will start the argument by supposing that one of the two delays is missing. This step is necessary to exhibit the conventional way to cope with the problem, which is to alternate information or production issues. Within this first step, we will see that the coordination of investments plans is in fact resolved spontaneously through market relations. Institutions are supposed to be necessary only to compensate market failures, as in traditional theories of the firm (second step). In that case, there exist decision rules implemented by firms, based on optimization programmes intended to guide the choice among given forms of business institutions. The third and last step of the argumentation will be dedicated to analysing how the coordination of both complementary and competitive investments will be attained. In this case decision rules depend upon the respective lengths of the two delays, conveying in a more determinate manner different types of coordination and thus of business institutions, including eventually market relations.

3.2.1. Information and production as alternative issues

If one of the two delays is missing, corrective measures concerning erroneous plans can be implemented either immediately or in a planned way. The ability to reappraise wrong choices through time implies the avoidance of any cumulative phenomenon, that is the avoidance of any failure in the coordination of complementary and competitive investments.

We will assume first that the information transmission period is null. This means that every decision maker within firm F has direct informational access to the actions of other firms. In other words, firm F is able to acquire both private and tacit information about other firms, this information being either complete or incomplete. For instance, decision makers within firm F may observe with certainty – or assign a probability distribution to – the

productive and strategic potentialities of rivals, as well as the evolution of their demand. In this case, if firm F is engaged in an irreversible investment which may imply an excess of supply on the market, it still has the opportunity to devise an optimal adjustment plan in order to reduce its undesired stocks through time. Because of its privileged access to information, firm F can choose the time periods and more generally the solutions that are best adapted to clear out the stocks.

Now let us assume that the investment gestation period is equal to zero. In this case the decision makers within firm F systematically give preference to flexible investment despite the fact that the resulting supply does not always meet the market demand. Excess demand or supply phenomena may appear but cannot persist. When information is given at the end of the delay, it can be freely used by firm F to implement some corrective procedures on its flexible investment strategies.

This argumentation needs some comments. It appears that coordination failures do not exist when only one delay is considered. The coordination problem is resolved by itself, as time passes, and without the need of a specific action of firm F (except stock inventories and flexible strategies adaptation).[6] The elimination of one of the two delays does not lead to uninteresting situations. There may exist real situations in which firms are quasi perfectly informed or in which they only engage in flexible strategies. However, economists must have something to say about the situations where firms are ignorant about both market knowledge and productive knowledge. These cases should be embodied in a more general framework which should be studied as a priority. However, this is not a dominant practice in the literature, especially in conventional theories of the firm.

3.2.2. Conventional theories of the firm: a classification

Most standard theories of the firm only take into account either one delay or the other, but never both of them simultaneously. These models can be divided into two categories.

The first category brings together models where the investment gestation delay exists, while the information transmission period is null. Game-theoretic models dedicated to problems of irreversible investment (Roberts and Weitzman, 1981; Bernanke, 1983; Dixit, 1992) fall into this first category. Basic games explain the situation where firm F has to develop an irreversible investment, while the environment (the 'nature') acts upon the profitability of this investment either in a good or a bad way. Firm F has to engage costs related to this investment at time 0, while receipts will only be perceived at time 1. If the project is profitable, then it is immediately implemented. Profitability has to be defined at time 0 on the basis of a given decision rule. The commitment to an irreversible investment is then reduced

to a point in time, the moment the decision maker of firm F examines the rule to calculate the profitability of its project. In these models, there is no information transmission period. The profitability of investment is derived from a given decision rule based on an intertemporal optimization method. Even if another player is introduced, a player different from Nature, its total potential actions are registered in a well-defined decision tree. The implementation of the intertemporal optimization method is conditioned by the timeless acquisition and the rational treatment of the relevant information.[7] Transaction cost analysis (Williamson, 1985) pertains also to this first category. Specific assets have an interesting characteristic implying that expenses which are engaged to obtain these assets cannot be reallocated to another use without additive costs. Firm F can work out organizational relations with its partners in order to manage this lock-in period for the best, namely through vertical integration or at least long-term contracts. However, the process of choice of the optimal governance structure is implemented according to the principle of 'institutional comparative analysis' which implies, firstly, the efficiency calculation of each institutional form and, secondly, their comparisons two by two in order to exhibit the optimal governance structure. Irreversibility problems implied by assets specificity are then solved by a particular governance structure which is derived from a cost-minimization decision rule. As before, the definition of such a decision rule depends on immediate access to information. These models, like the preceding ones, neglect the information transmission period.

The second category is composed of models in which the information transmission period is considered as positive while the investment gestation delay is null. The property rights approach (Grossman and Hart, 1986; Hart, 1988; Hart and Moore, 1988, 1990) is certainly one of the most typical cases of this category. In this analysis, information is delayed through time. This is why firms decide in the first period to conclude a contract which is not (and cannot be) optimal, but allows them nevertheless to cope with strong uncertainty for a time. According to the contract, one single firm (firm F) is endowed with all the residual rights, just as in a pure integration case. As the second period begins, uncertainty is resolved. The delay of information transmission is then brought to completion and optimal choices are revealed. The uninformed initial contract of vertical integration can immediately and without cost be transformed into an informed and optimal ex post contract. According to the available information, firms have the ability to reappraise their choices without being limited by the slightest irreversibility constraint of some investment which could have been engaged in the first period.

3.2.3. Coordination failures and business institutions

As we have seen in the two preceding paragraphs, if the theory takes into account only one delay, the coordination problem is resolved more or less spontaneously, the role of business institutions being reduced to the compensation of market failures. In fact, a real coordination failure only appears when the two delays are considered simultaneously. Here we will assume that the two delays are present even if we allow one or both of them to be equal to zero. This assumption will be used to design the specific role of each kind of business institution, the market itself being considered as an alternative among others.

When firm F is engaged in a reversible investment programme, the investment gestation delay can be considered as null. Firm F is then endowed with a perfect flexibility of action the performance of which depends exclusively on the availability of information. The objective of this firm is to maintain continuous access to new information in order to be able to adjust the investment programme in the right way. The main problem of the firm is then to secure a suitable potentiality of reaction of its own that must be sufficiently rapid to benefit from the acquisition of new information. In this case formal relations like cooperation or integration are not necessary to resolve the coordination problem. In fact, by their organizational and informational network characteristics, these formal relations could be useful for firm F to acquire information. But, at the same time, the requirement of a perfect adaptation capability of the firm would be hindered by the very fact of participating in this network, the working of which is conditioned by behavioural constraints of its participants. Indeed, market relations seem to be the institutional form that is best adapted to resolve coordination when the delay of investment gestation is equal to zero.

Market relations are also appropriate when the delay of information transmission is assumed to be null. All pieces of information are already known at the time the irreversible investment is implemented (costs, receipts, time of their receipts and so on). As in the preceding case, the elaboration of formal relations is not justified because the coordination problem tends to be resolved by itself, either immediately or in a planned way.

Formal organizations are then only needed when a real coordination failure may appear, that is when firm F faces both information transmission and investment gestation periods. In this situation, the competitors of firm F are prompted to implement well-defined flexible strategies that may question the profitability of the firm and hence its viability. The strategies implemented by rivals are likely to be successful because firm F is locked into its irreversible project and cannot work out defensive plans. Furthermore, unknown events may lead to some additional negative effects. Firm F therefore has to set up suitable actions beforehand so that durable and

cumulative disequilibria do not emerge. These actions are intended, first, to acquire information about external strategies which does not appear spontaneously and, second, to make possible the development of the innovation, especially by ensuring the interdependency and the sequentiality of the different stages. These are continuity and constraint requisites which can only be ensured by implementing business institutions.

In fact, when innovation is systemic, this implies that both the information transmission period and the investment gestation period are very long. This means, respectively, (a) that firm F has to create information about the strategies that other firms can implement, and (b) that firm F has to develop at the same time means of coordination of the whole development stages of the innovative process, especially by creating new capabilities. In this case, pure integration seems to better solve the coordination problem of complementary and competitive investments.

If an autonomous innovation is implemented, both delays are shorter. This means that (a) firm F has to improve its knowledge about the strategies of the other firms, and (b) firm F has to coordinate only some stages of the innovation process by making available adapted capabilities internally and externally. Cooperation between firms will then be appropriate.

Finally, if either one or the other delay is very short, indeed even null, innovation is absent. This means that (a) firm F has perfect information on the strategies of other firms, and (b) firm F does not implement an irreversible investment: informal market relations will suffice to resolve the coordination problem.

These results are consistent with Langlois and Robertson (1995b) and with Teece (1996). However, a more complete view of the interactions between firms within the process of competition is proposed because the two delays refer to the capabilities and also to the strategies implemented by the firms. In particular, this view has a competition policy significance that can be sketched briefly. For instance, all agreements should be questioned by competitive authorities if either one or the other delay is very short of null, that is when partners enjoy an informational advantage about market behaviour or when they plan to commit purely flexible investments. The elaboration of an integration should be examined in detail if the lengths of the two delays are short. On the other hand, however, the authorities should accept and even encourage the setting up of cooperation agreements (indeed, even pure integration) as soon as time periods for the acquisition of information and the gestation of investments are found to be long (indeed, even very long). Nevertheless, once the two delays have expired – and then once the common project is brought to completion – the agreement is no longer justified and has to be cancelled.

4. CONCLUDING REMARKS

The first comment is that adding a productive dimension to an already defined problem of informational coordination is simply a matter of increasing the complexity of the analytical framework. Considering the productive dimension gives an opportunity to be more specific about the different types of coordination problems. The informational searching process taken as a mere object of study leads economists to describe only temporary disequilibria. This can also be said when only the investment gestation delay is analysed. Conversely, examining how to create the informational basis that is required in order to develop to completion an irreversible project opens the door to coordination problems which are not immediately resolved. To be maintained within a viability corridor, these coordination failures call for specific business institutions.

The second comment is that considering the productive dimension also allows us to appreciate the causal relation that may exist between the nature of the coordination problem and the institutional form to be implemented. When authors study the informational coordination problem itself, they integrate institutions whose function is to compensate for information processing failures: that is, to reduce information costs and align incentives. As soon as informational problems are linked to productive coordination concerns, business institutions are thereby endowed with a more general function, informational processing being just part of it. The function of business institutions is to make industrial coordination feasible, that is to maintain the viability of an industrial system where firms have local information sets and different productive projects, the distinct stages of which have to be coordinated in a specific manner. The above analysis permits us to distinguish the different institutional forms according to their individual functions.

The last comment is that, within the framework we have proposed, the economic system does work, not despite informational and productive imperfections, but on the contrary because of them. Price fixing, product differentiation, reputation and organizational arrangements are indeed implementable measures that may create the continuity and constraint conditions that are required to develop future projects.

NOTES

1. This sentence is underlined by Böhm (1995, p.166).
2. Walras's *'tâtonnement'* process is one way to meet the first requirement (the other way being Edgeworth's *'recontracting'*). However, this iterative search procedure for determining equilibrium prices in a system of interdependent demand and supply equations

fails as soon as delays or costs of transactions come into the picture. Expressed in the terms of computable economics (cf. Leijonhufvud, 1993, p.8), the statement that 'there is no auctioneer' (Leijonhufvud, 1968, p.76) implies that 'there is no central processor' able to solve the coordination problem. The allocation of resources computation is made by markets and agents acting as parallel computers. 'The array of markets runs algorithms that iterate on the basis of effective excess demands' (ibid.). When the sign of some elements of the excess demand vector differs from the one of the corresponding notional elements, the 'parallel' and the 'centralized' computers do not give the same answer.

3. This algorithm is stated only on general terms. It is mainly a pattern rather than a model of computational analysis.
4. See Leijonhufvud (1968, p.70, fn.5) who, referring to Richardson's 1959 paper, chose to stick to a perfect primary information hypothesis.
5. Within this framework, there is an important and pioneering attempt to integrate the demand side and not only the supply side. For example, in the case of systemic innovation, the product ('appliance') brings together in a single standardized package components that provide all the desired attributes. Vertical integration is in this case the adequate organizational form. In the case of an autonomous innovation, the product is a modular system which is acquired bit by bit, allowing consumers to construct themselves the package that meets their individual preferences for attributes. This framework thus tries to provide a consistent analysis of institutions and innovation, the latter being analysed through its firm and final customers sides.
6. In fact, this leads back to Hayek's case of spontaneous coordination with exogenous institutions.
7. It is noteworthy that, under these conditions, the notion of irreversible investment is questionable. At the time the engagement is made, the ability to synchronize costs and receipts is already expected and planned by the decision rule (at time 0). If these means were indeed not expected at that time, the investment would not be implemented just because it would not be profitable. We shall note that this interpretation does not fit with the sunk costs definition in which the synchronisation has to be worked out through time by the firm itself.

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